

CLAIMS

1. A method for use in solid freeform fabrication, the method comprising:
 - receiving a computer-aided design (CAD) model in a cross-platform compatible format, the CAD model comprising at least one untessellated mathematical representation of one or more surfaces; and
 - adaptively slicing at least one of the surfaces in the CAD model to produce at least a first set of sliced data.
2. The method of claim 1 wherein adaptively slicing at least one of the surfaces in the CAD model to produce at least a first set of sliced data comprises:
 - determining a plurality of bounding boxes on the at least one surface;
 - casting a ray within a slicing plane;
 - determining which of the bounding boxes the ray passes through; and
 - for each of the determined bounding boxes which the ray passes through, determining at least one intersection point of the ray and the at least one surface of the CAD model.
3. The method of claim 1 wherein adaptively slicing at least one of the surfaces in the CAD model to produce at least a first set of sliced data comprises:
 - determining a number of slicing planes;
 - for each of the determined slicing planes, subdividing the at least one surface of the CAD model into a plurality of domains;
 - determining a plurality of bounding boxes based on each of the domains;
 - for each of a number of positions within the slicing plane, casting a ray at the position within the slicing plane;
 - determining which of the bounding boxes the ray passes through; and

for each of the bounding boxes through which the ray passes, determining at least one intersection point of the ray and the at least one surface of the CAD model.

4. The method of claim 3, further comprising:

optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model before adaptively slicing the at least one of the surfaces in the CAD model to produce the at least a first set of sliced data.

5. The method of claim 3 wherein determining a plurality of bounding boxes based on each of the domains comprises determining a plurality of parallelepipeds having a number of edges, the edges of each parallelepiped oriented parallel to a set of coordinate axes of the CAD model.

6. The method of claim 3 wherein determining a plurality of bounding boxes based on each of the domains comprises determining a size of each of the bounding boxes based on an amount of curvature of a portion of the at least one surface of the CAD model inside a respective one of the bounding boxes.

7. The method of claim 3 wherein determining a plurality of bounding boxes based on each of the domains comprises determining a size of each of the bounding boxes sufficiently small to contain no more than one intersection point of the ray and the at least one surface of the CAD model.

8. The method of claim 3 wherein determining at least one intersection point of the ray and the at least one surface of the CAD model comprises iteratively bisecting the bounding boxes until the first of 1) an error value is within a defined tolerance and 2) the number of iterations exceeds a defined threshold number of iterations.

9. The method of claim 8 wherein determining at least one intersection point of the ray and the at least one surface of the CAD model comprises iteratively bisecting the bounding boxes using at least one of linear interpolation, Newton iteration and fixed point iteration.

10. The method of claim 3 wherein determining the intersection point of the ray and the at least one surface of the CAD model further comprises for each of the intersection points characterizing the intersection point as one of an entrance point, an exit point and an edge point.

11. The method of claim 3 wherein determining a number of slicing planes comprises determining successive slicing planes separated from one another by a thickness corresponding to a thickness of a layer used in a layered manufacturing technique.

12. The method of claim 1 wherein receiving a computer-aided design (CAD) model in a cross-platform compatible format, the CAD model comprising at least one untessellated mathematical representation of one or more surfaces comprises receiving a STEP file comprising a non-uniform rational B-spline representation of the at least one surface representing a three-dimensional solid CAD model.

13. The method of claim 1, further comprising:
determining a set of process planning instructions for three-dimensional printing based on the sliced data, the set of processing planning instructions comprising a raster pattern of points extending between an entrance intersection point and an exit intersection point.

14. The method of claim 4 wherein optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model comprises:

- mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

- determining which of the first rotations of the CAD model produces at least one of a minimum height of a build bed, a minimum volume of supports and a minimum surface area of stair case effect, in three-dimensional printing;

- mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations;

- determining which of the second rotations of the CAD model produces at least one of a minimum height of a build bed, a minimum volume of supports and a minimum surface area of stair case effect, in three-dimensional printing; and

- translating the determined second-rotated CAD model.

15. A computer-readable medium storing instructions for causing a computer to produce sliced data use in solid freeform fabrication, by:

- receiving a computer-aided design (CAD) model in a cross-platform compatible format, the CAD model comprising at least one untessellated mathematical representation of one or more surfaces; and

- adaptively slicing at least one of the surfaces in the CAD model to produce at least a first set of sliced data.

16. The computer-readable medium of claim 15 wherein the instructions cause the computer to adaptively slice the at least one of the surfaces in the CAD model to produce at least a first set of sliced data by:

- determining a number of slicing planes;

- for each of the determined slicing planes,

subdividing the at least one surface of the CAD model into a plurality of domains;

determining a plurality of bounding boxes based on each of the domains;

for each of a number of positions within the slicing plane, casting a ray at the position within the slicing plane;

determining the bounding boxes which the ray passes through; and

for each of the bounding boxes through which the ray passes, determining at least one intersection point of the ray and the at least one surface of the CAD model.

17. The computer-readable medium of claim 15 wherein the instructions cause the computer produce sliced data for use in solid freeform fabrication, further by:

optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model before adaptively slicing the at least one of the surfaces in the CAD model to produce the at least a first set of sliced data.

18. The computer-readable medium of claim 15 wherein the instructions cause the computer to determine a plurality of bounding boxes based on each of the domains by:

determining a size of each of the bounding boxes based on an amount of curvature of a portion of the at least one surface of the CAD model inside a respective one of the bounding boxes.

19. A computer programmed to produce sliced data use in solid freeform fabrication, the computer comprising:

means for receiving a computer-aided design (CAD) model in a cross-platform compatible format, the CAD model comprising at least one untessellated mathematical representation of one or more surfaces; and

means for adaptively slicing at least one of the surfaces in the CAD model to produce at least a first set of sliced data.

20. The computer of claim 19 wherein the means for adaptively slicing the at least one of the surfaces in the CAD model to produce at least a first set of sliced data comprises:

means for determining a number of slicing planes;

means for subdividing the at least one surface of the CAD model into a plurality of domains;

means for determining a plurality of bounding boxes based on each of the domains;

means for casting a ray at the position within the slicing plane;

means for determining the bounding boxes the ray passes through; and

means for determining at least one intersection point of the ray and the at least one surface of the CAD model for each of the bounding boxes through which the ray passes.

21. The computer of claim 19, further comprising:

means for optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model before adaptively slicing the at least one of the surfaces in the CAD model to produce the at least a first set of sliced data.

22. A method for use in solid freeform fabrication, the method comprising:

receiving a computer-aided design (CAD) model in a cross-platform compatible format, the CAD model comprising at least one untessellated mathematical representation of one or more surfaces; and

optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model.

23. The method of claim 22 wherein optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model comprises:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis; and

determining which of the first rotations of the CAD model produces a minimum value of at least one of: a build height, a volume of supports and a stair cased surface area.

24. The method of claim 22 wherein optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model comprises:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis; and

determining which of the first rotations of the CAD model produces a minimum value of at least two of: a build height, a volume of supports and a stair cased surface area.

25. The method of claim 22 wherein optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model comprises:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

determining which of the first rotations of the CAD model produces a minimum value of at least one of: a build height, a volume of supports and a stair cased surface area;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations; and

determining which of the second rotations of the CAD model produces a minimum value of at least one of: the build height, the volume of supports and the stair cased surface area.

26. The method of claim 22 wherein optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model comprises:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

determining which of the first rotations of the CAD model produces a minimum value of at least two of: a build height, volume of supports and a stair cased surface area according to a first weighting;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations; and

determining which of the second rotations of the CAD model produces a minimum value of at least one of: the build height, the volume of supports and the stair cased surface area according to a second weighting.

27. The method of claim 22 wherein optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model comprises:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

determining which of the first rotations of the CAD model provides a minimum height of a build bed in three-dimensional printing;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations; and

determining which of the second rotations of the CAD model produces a minimum height of the build bed in three-dimensional printing.

28. The method of claim 22 wherein optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model comprises:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

determining which of the first rotations of the CAD model provides a minimum height of a build bed in three-dimensional printing;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations, the second axis orthogonal to the first axis; and

determining which of the second rotations of the CAD model produces the minimum height of a build bed in three-dimensional printing.

29. The method of claim 22 wherein optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model comprises:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

determining which of the first rotations of the CAD model provides a minimum height of a build bed in three-dimensional printing;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations, the second axis orthogonal to the first axis;

determining which of the second rotations of the CAD model produces a minimum height of the build bed in three-dimensional printing; and

translating the determined second-rotated CAD model.

30. The method of claim 29 wherein mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis comprises applying the transformation defined by:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\theta) & -\sin(\theta) \\ 0 & \sin(\theta) & \cos(\theta) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

where X,Y,Z represent control points of different NURBS surfaces of the CAD the model, X',Y',Z' represent a set of new control points resulting from the transformation, and θ represents an angle of transformation, and wherein mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations, the second axis orthogonal to the first axis comprises applying the transformation defined by:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} \cos(\theta) & 0 & -\sin(\theta) \\ 0 & 1 & 0 \\ \sin(\theta) & 0 & \cos(\theta) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}.$$

31. The method of claim 30, further comprising,
adaptively slicing at least one of the surfaces in the CAD model to produce
at least a first set of sliced data.

32. A computer-readable medium storing instructions for causing a computer produce model data for use in solid freeform fabrication, by:

receiving a computer-aided design (CAD) model in a cross-platform compatible format, the CAD model comprising at least one untessellated mathematical representation of one or more surfaces; and

optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model.

33. The computer-readable medium of claim 32 wherein the instructions cause the computer to optimize the at least one untessellated mathematical representation of one or more surfaces of the CAD model by:

- mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

- determining which of the first rotations of the CAD model produces a minimum value of at least one of: a build height, a volume of supports and a stair cased surface area;

- mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations; and

- determining which of the second rotations of the CAD model produces a minimum value of at least one of: the build height, the volume of supports and the stair cased surface area.

34. The computer-readable medium of claim 32 wherein the instructions cause the computer to optimize the at least one untessellated mathematical representation of one or more surfaces of the CAD model by:

- mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

- determining which of the first rotations of the CAD model produces a minimum value of at least two of: a build height, volume of supports and a stair cased surface area according to a first weighting;

- mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations; and

- determining which of the second rotations of the CAD model produces a minimum value of at least one of: the build height, the volume of supports and the stair cased surface area according to a second weighting.

35. The computer-readable medium of claim 32 wherein the instructions cause the computer to optimize the at least one untessellated mathematical representation of one or more surfaces of the CAD model by:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

determining which of the first rotations of the CAD model provides a minimum height of a build bed in three-dimensional printing;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations, the second axis orthogonal to the first axis; and

determining which of the second rotations of the CAD model produces a minimum height of the build bed in three-dimensional printing.

36. The computer-readable medium of claim 32 wherein the instructions cause the computer to optimize the at least one untessellated mathematical representation of one or more surfaces of the CAD model by:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis according to the transformation:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\theta) & -\sin(\theta) \\ 0 & \sin(\theta) & \cos(\theta) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix};$$

determining which of the first rotations of the CAD model provides a minimum height of a build bed in three-dimensional printing;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations according to the transformation:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} \cos(\theta) & 0 & -\sin(\theta) \\ 0 & 1 & 0 \\ \sin(\theta) & 0 & \cos(\theta) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix},$$

the second axis orthogonal to the first axis; and

determining which of the second rotations of the CAD model produces the minimum height of a build bed in three-dimensional printing.

37. A computer programmed to produce model data use in solid freeform fabrication, by:

receiving a computer-aided design (CAD) model in a cross-platform compatible format, the CAD model comprising at least one untessellated mathematical representation of one or more surfaces; and

optimizing the at least one untessellated mathematical representation of one or more surfaces of the CAD model.

38. The computer of claim 37 wherein the instructions cause the computer to optimize the at least one untessellated mathematical representation of one or more surfaces of the CAD model by:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis;

determining which of the first rotations of the CAD model produces a minimum value of at least two of: a build height, volume of supports and a stair cased surface area according to a first weighting;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations; and

determining which of the second rotations of the CAD model produces a minimum value of at least one of: the build height, the volume of supports and the stair cased surface area according to a second weighting.

39. The computer of claim 37 wherein the instructions cause the computer to optimize the at least one untessellated mathematical representation of one or more surfaces of the CAD model by:

mathematically rotating the CAD model incrementally through a plurality of first rotations about a first axis according to the transformation:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\theta) & -\sin(\theta) \\ 0 & \sin(\theta) & \cos(\theta) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix};$$

determining which of the first rotations of the CAD model provides a minimum height of a build bed in three-dimensional printing;

mathematically rotating the determined first-rotated CAD model about a second axis incrementally through a plurality of second rotations according to the transformation:

$$\begin{bmatrix} X' \\ Y' \\ Z' \end{bmatrix} = \begin{bmatrix} \cos(\theta) & 0 & -\sin(\theta) \\ 0 & 1 & 0 \\ \sin(\theta) & 0 & \cos(\theta) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix},$$

the second axis orthogonal to the first axis; and

determining which of the second rotations of the CAD model produces the minimum height of a build bed in three-dimensional printing.